

Final Report

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Materials Processing in Low Gravity

by

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1.0 Introduction

This report covers the continuation of the Materials Processing in Low Gravity Program in which The University of Alabama in Huntsville designed, fabricated and performed various low gravity experiments in materials processing from November 7, 1989 through November 6, 1990. The facilities used in these short duration low gravity experiments include the Drop Tube and Drop Tower at MSFC, and the KC-135 aircraft at Ellington Field.

During the performance of this contract, the utilization of these ground-based low gravity facilities for materials processing experiments has been instrumental in providing the opportunity to determine the feasibility of performing a number of experiments in the microgravity of Space, without the expense of a space-based experiment.

Since the KC-135 was out for repairs during the latter part of the reporting period, a number of the KC-135 activities concentrated on repair and maintenance of the equipment that normally is flown on the aircraft.

A number of periodic reports have been given to the TCOR during the course of this contract, hence this final report is meant only to summarize the many activities performed and not redundantly cover materials already submitted.

2.0 Tasks Accomplished

2.1. In collaboration with scientists from MSFC and industry, UAH has defined, developed, and conducted materials processing experiments in low gravity using the Drop Facilities at MSFC and

the KC-135 aircraft at Ellington Field. This effort has included the defining of experimental requirements and equipment, experiment-facility integration requirements, building/assembling the necessary experiment apparatus, and conducting experiments which will contribute to the knowledge base for commercialization of materials processing in low gravity. UAH has also performed the logistical support needed to execute the experimentation, and the necessary sample preparation, metallography analysis/interpretation and physical properties measurements of processed samples. UAH has interfaced with designated MSFC scientists and project representatives who will provide Center policy, programmatic requirements and goals, priorities, and scientific and technical advice.

2.1.1.1. All ground based facilities have been very productive during the duration of this contract. The Drop Facilities at MSFC are worked daily to perform drop experiments, build up experimental hardware for drops, and provide maintenance on existing instrumentation. Dr. Mike Robinson has provided the leadership for MSFC in over-seeing this facility and its function within NASA's materials processing program. Tom Rathz is in charge of the UAH activities at the Drop Facilities and works quite closely with Dr. Robinson in determining and meeting scientific objectives at the Drop Facilities.

Current experimental hardware which is being used still includes the following:

DROP TUBE: Electromagnetic Levitation Furnace.

Electron Beam Furnace.

DropP Tower: Critical Point Wetting Experiment

High Temperature Vacuum Furnace

2.1.2 UAH supported the KC-135 for seven missions during the contract period. Scheduling of the aircraft is performed by Dr. Robert Shurney of MSFC with the UAH personnel adhering to that predetermined schedule. Slippages due to aircraft down-times are the major reasons for any cancellations in scheduled aircraft experiments, and during this contract the crack in the landing gear of the KC-135 was the limitation in performing KC-135 experiments.

The primary experimental hardware which is being used for KC-135 experiments still includes the Advanced Directional Solidification Furnace (ADSF) and the Isothermal Casting Furnace (ICF). In addition UAH has assisted in the transport of an Orbital Tube Welder Experiment provided by Richard Poorman of MSFC and used by Rocketdyne personnel in their Welding in Space experiment. Also a Laser Welding experiment for UAH has been transported to JSC on a number of occasions. In addition we have assisted in transporting and flying two new furnaces for SSL, the Rapid Melt/Rapid Quench solidification experiment and the Polymer Video Furnace to fly on the KC-135.

2.1.3. UAH is fortunate to continue with experienced personnel with no extended down times and has continued to maintain a

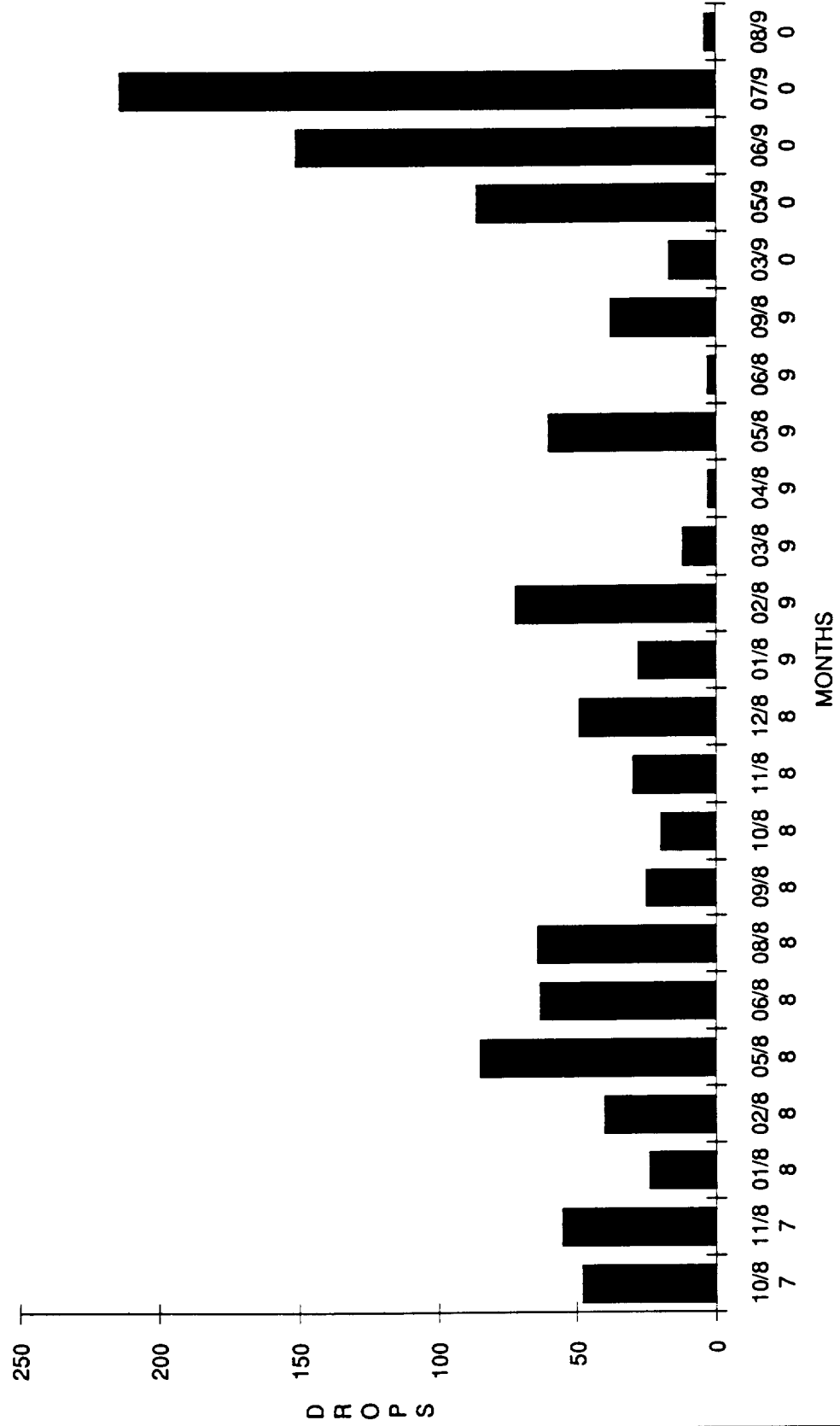
productive capability. As an example of the continued progress made in the productivity of the Drop Tube, the chart below lists the number of drop tube experiments made at the facility during FY90, in comparison with the previous two years.

DROP TUBE PRODUCTIVITY

MONTH	DROPS	MONTH	DROPS		
10/87	48	10/88	20		
11/87	55	11/88	30		
		12/88	49		
1/88	24	1/89	28		
2/88	40	2/89	72		
		3/89	12	3/90	17
		4/89	3		
5/88	85	5/89	60	5/90	86
6/88	63	6/89	3	6/90	151
				7/90	214
8/88	64			8/90	4
9/88	<u>25</u>	9/89	<u>38</u>		

TOTALS	404	315	472
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FIGURE 1. DROP TUBE PRODUCTION FY88 - FY90



being able to make drops during that time period. The months in which no data are shown were months when either equipment breakdown or testing occurred or on occasion, testing and installation of new equipment on the facility was necessary or due to sand-blasting.

In FY90, the primary interruptions were the use of the drop tube for a Tethered satellite test in January and maintenance and set-up for the Nb drops for Mike Robinson. In addition UAB made 49 drops with AuRh in May. Barry Andrews is the Principal Investigator for that experiment.

2.1.5 The Drop Tower has also continued in becoming more productive during this contractual period. Mr. Jeff Sinex is in charge of the facility and although he is still new to this type of operation, he has performed well.

Over the last several years, several major repairs to the tracks have been performed to eliminate any accelerations during the drop and the nose section of the drag shield has been reinforced. Some attempts were made to modify the catch tube's air flow pattern to ameliorate the maximum G's at the end of the drop; however, either the drag shield hit with a thump or it bounced several times. Either occurrence was undesirable, therefore we ended up with partial air flow to be in the middle. As addressed later on, we have also made progress in improving the data acquisition for Drop Tower experiments.

No official experiments were performed during this period at the Drop Tower. In implementation of a 'shut-down' procedure, Jeff Sinex has performed several drops to characterize optimal floating

environments for drop experiments. Dr. William Kaukler assisted Jeff in these experiments. Duplication of some parameters observed in previous drops for both Dr. Kaukler, Dr. M. K. Wu and Dr. Mohri were performed. During this period the Drop Tower production rate was up to around 22 official drops, which includes all the test drops for checking out particular components of an experiment package or the drag shield itself.

2.1.6. The KC-135 activities have also been quite active during this contract period. For this task we have been primarily concerned with experiments that have been performed with the ADSF and the ICF furnaces. Scientific investigators for these furnaces include many collaborations that Dr. Pete Curreri has established with the University of Alabama in Tuscaloosa, Rockwell International, and UAH.

Dr. Donald E. Morel for Applied Research Laboratory was the principal investigator for studying metal matrix composites. The Rapid Melt/Rapid Quench furnace was flown by our group to perform such experiments. Limited capability still exists with the RM/RQ, even after we made several modifications in Delivery Order #21. Dave Mathiesen of GFE and The Clarkson University consortium have also flown using the polymer video furnace. Dr. Marcus Vlasse of SSL began taking the lead with that furnace. Guy Smith worked with both groups in performing ground-based studies to prepare for the parameters needed in flight and each furnace was flown twice, before the decision was made that they were very awkward to coordinate with the KC-135 logistics.

Consequently a new twist on the ADSF this year has been Guy's modification to the ADSF to perform rapid melt/rapid quench experiments. Two series of experiments were performed with the modification. Several of Don Morel's samples and several of a Purdue undergraduate, Ms. Beth Stubbins were flown. Ms. Stubbins samples were tin/zinc carbonate foam metal experiment. Both experiments proved to be successes for the ADSF experiment. However, the ADSF modification still does not completely replace the RM/RQ. Its overall capability, particularly in temperature range is still preferred.

The lack of a large number of experiments suggests that results from these types of experiments may not be as easily understood in terms of what goals are set for KC-135 experiments. For instance if an experimenter anticipated the type of data obtained is a space-based experiment or if he under-estimates the work required to interpret the directional solidification results properly, then the utility of the KC-135 as an experimental platform may be received negatively. Perhaps this indicates that the program should provide a better understanding of what experimental results can be achieved in the KC-135 environment. To help meet that end, Dr. Kaukler and I have submitted a request to develop a video convective flow analyzer to determine what fluid flows mechanisms do exist as the KC-135 flies parabolic maneuvers. In anticipation that it is funded, the information will be valuable to many KC-135 experimentalists.

2.0 UAH has developed procedures delineating the

objectives, test sequence, operational timeline, etc. prior to each experiment or experiment series, This has included ground-based checkout of experiment apparatus and support systems, both for pre-experiment/flight and ground control, and installing and testing suitable apparatus in the facilities in order to provide the appropriate processing conditions required for the experimental work. UAH has recorded and analyzed experiment apparatus operation parameters and thermal profiles as appropriate to interpret results of the experiments during the contract period. Existing apparatus such as E-beam furnaces, dropper furnaces, and levitation devices have been made available to the contractor on an "as available" basis. Scheduling of apparatus and facilities has been done through the designated MSFC coordinator, Dr. Michael Robinson of SSL.

2.2.1. UAH personnel have continued work on performing tests and check-outs on all facilities as part of the facilities requirements. The Drop Facilities need extensive mechanical and electrical preventative maintenance, which UAH is not authorized to perform. SSL does provide technician support for this activity. This arrangement works well, since the technician can interface more easily with MSFC facilities and supply personnel.

2.3. Where required UAH has formulated written scientific and/or engineering reports for each experiment and/or experiment series. These reports were augmented with metallurgical reports where appropriate and were provided on a timely basis for internal

program use. No reports or publications intended for distributions to other organizations or individuals included data furnished to NASA with restrictive legends by third parties.

2.3.1. After the experiments are performed, each scientific investigator for each facility or experiment receives their samples, the data derived from each experiment, and any additional comments which might assist in the interpretation of the experiment. For the Drop Tube this data set include pyrometric data, pressure measurements, and electrical parameters effecting the molten droplet. For the Drop Tower this data includes acceleration profiles, temperatures, and other pertinent parameters. For the KC-135 experiments the data includes strip charts and computer data files with temperature, acceleration, and position of sample.

A useful experiment conducted during this contract in which accelerometer data was collected from several different flight profiles; i.e. good weather and poor weather conditions. In comparison some data from a free-floating accelerometer package is shown in comparison in Figure 2 on the next page.

2.4. UAH has provided consultation, expert interpretation of experiment results of metallurgical and chemical processes, expert analysis and interpretation of optical records taken during low gravity experiments, and recommendations for research tasks being conducted under this contract.

FIGURE 2. COMPARISONS BETWEEN A 'GOOD' AND A 'BAD' LOW G PERIOD

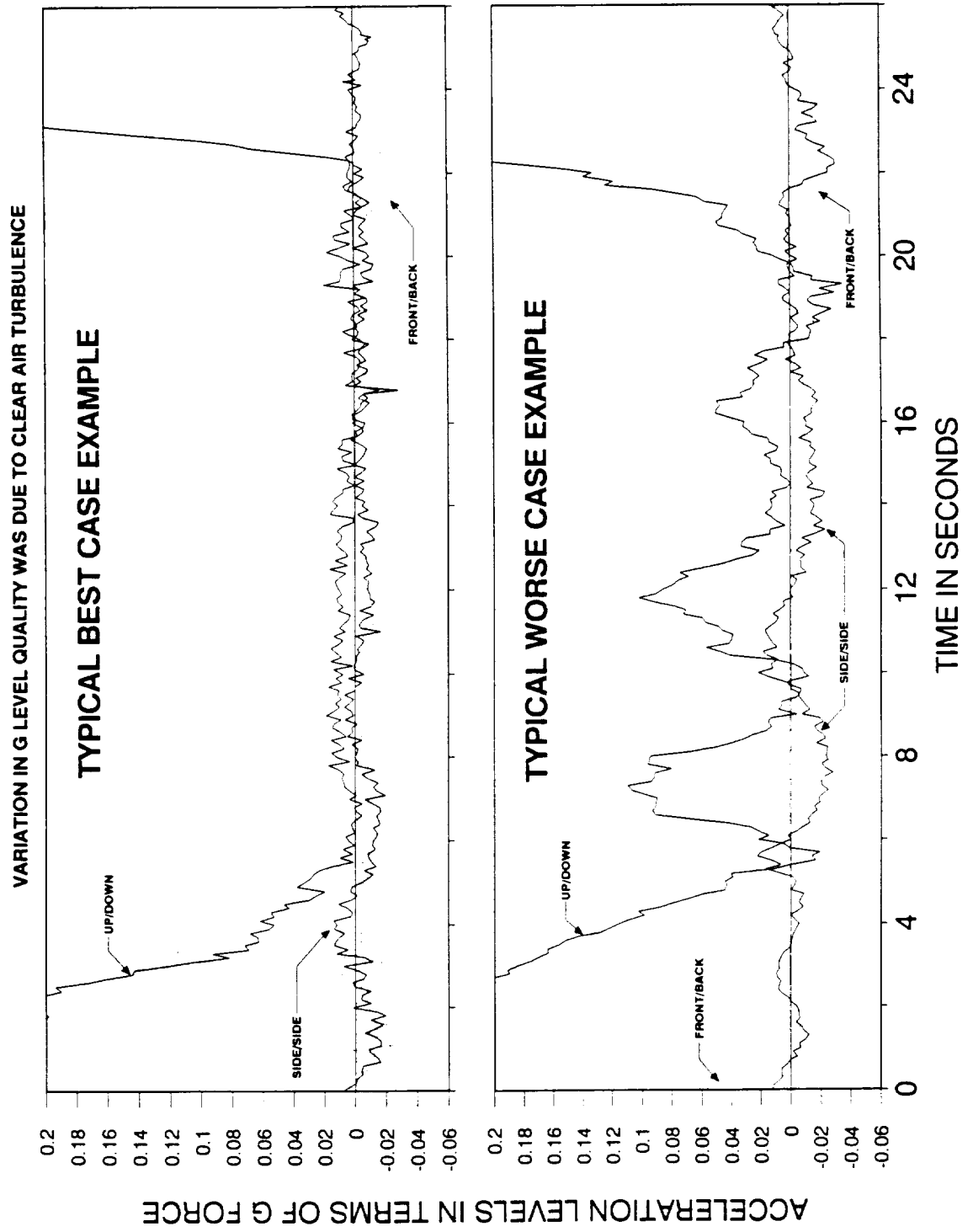
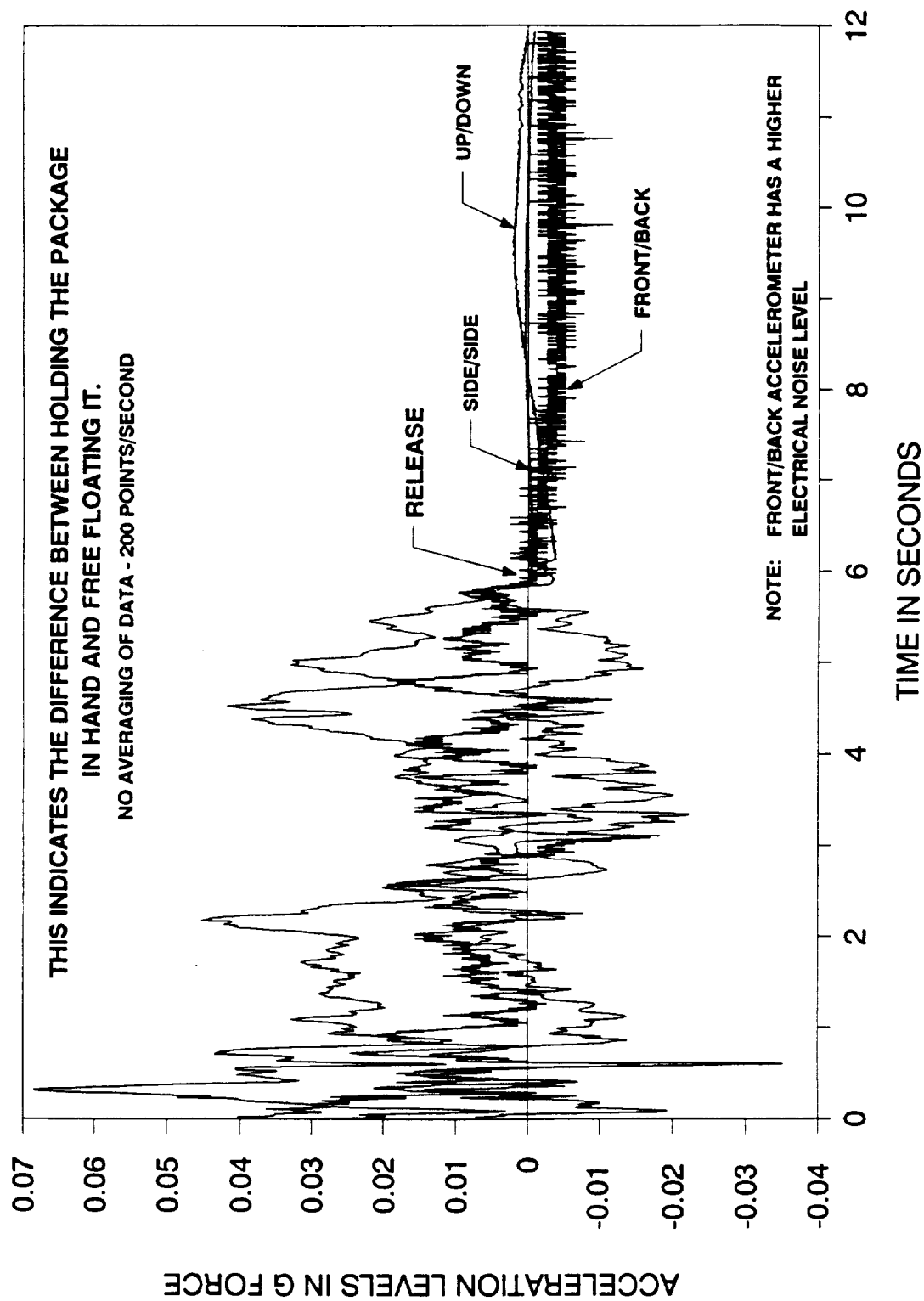


FIGURE 3. ACCELEROMETER DATA FOR A FREE FLOATING PACKAGE



DATA FROM PORTABLE ACCELEROMETER PACKAGE
FILE ID: ACCEL2, MAY 9, 1990

2.4.1. This activity has in general been performed upon request from other groups using or wishing to use the ground-based facilities. Both Guy Smith for the KC-135 operations and Tom Rathz for the Drop Facilities have responded to numerous requests about particular features of performing experiments in those facilities. Dr William Kaukler has also assisted in responding to outside requests for information about use of the facilities or general information about experimentation in low gravity. In addition, we have received many visiting groups at the Drop Facilities which have been escorted through by Public Affairs Office at MSFC.

Guy Smith has provided some expert advise in the fabrication of furnace cores to a number of groups who are building furnaces. His expertise has developed over the years and it continues to be beneficial to the NASA MPLG program in a number of different ways. He has also been able to train student workers in the art of winding the furnace cores such that we are able to provide assistance when needed.

2.4.2. In general other than tour groups visiting the Drop Facilities, we have not been requested by too many outside groups to provide expertise on low gravity materials processing. Due to the nature and the diversity of the many experiments we perform at the various facilities, we feel that we should be more beneficial to the program than we currently are. An accumulation of knowledge from building many experimental packages at the various facilities is certainly useful in designing a scientific experiment for space, that would benefit from preliminary experiments at any of

of the facilities for low gravity experiments and not on reporting of any experimenter's results.

2.5. UAH has maintained procedures to protect proprietary and trade secret data provided by an industrial organization from unauthorized disclosure.

2.5.1. UAH has performed this task accordingly by not publishing or sending anyone's data to anyone other than the scientific investigator himself. The TCOR, in this case Dr. Robinson, is always consulted before sending out any information which is not already in the public domain. We have made general presentations about Materials Processing in Low Gravity, but only used information currently open to the public or already published. Dr. Pete Curreri for KC-135 experiments and Dr. Mike Robinson for the Drop Facilites serve as the officials who determine what information can be transmitted.

A concern of mine, of which the philosophy of this task basically helps to propagate, is that officially we are authorized only to transmit the data and the samples to the scientific investigators. We have no mechanism for the investigators to share with us the results of the experiments. Unfortunately this

information would be useful for the purpose of maintaining optimal control of the experimental parameters and hardware. Since we do not in general get feedback from the scientific investigators about their scientific results, we are quite limited in determining if our experiments are really what the investigator

wanted. Thus this feedback could be used to determine any future modifications or experimental changes required to optimize upon particular experiments.

2.6. UAH has conducted various experimental drops, as directed, associated with operational readiness demonstrations of the drop tube facility and scientific investigations.

2.7. Since the recording of droplet temperatures as a function of drop time in the Drop Tube is such an important part of most Drop Tube experiments, it is necessary to continue to search for and evaluate for the most cost effective method for determining transit droplet temperature along the length of the Drop Tube in order to make recommendations for implementation of such a method or methods. Upon specific direction procure, install and verify equipment and/or instrument required to implement the preferred method.

2.7.1. This problem has a long standing thrust in materials processing experiments in low gravity. Non-contact temperature measurement is required to understand solidification phenomena, fluid behavior, etc in containerless environments. The most progress has occurred since Tom Rathz has taken charge of the facility and Boyd Shelton was hired to respond to electronic instrumentation requirements at the Drop Facilities.

2.7.2. Over the years additional work and analysis have been

performed by members of our group, Tom Rathz and Dr. William Kaukler and by others such as Dr. William Hofmeister of Vanderbilt University. Alternatives included high gain Si detectors, temperature stabilized Si detector, and logarithmic amplifiers. Boyd Shelton has continued to work with improving the capability of the Si detector system, performing experiments in parallel with other activities at the Drop Facilities. We currently believe that this method will perform adequately for the tasks at hand when fully optimized. Tom Rathz has continued development of quartz light-pipes at the Drop Tube, thereby increasing the quantity of radiance from recalescence collected by the detectors. They see noticeable improvements in the S/N level of these signals.

2.7.3 Tom Rathz has been able to participate to some extent with the Non-contact Temperature Measurement Working Group. Thus he is able to at least keep abreast of other techniques which are being considered in NASA's various programs.

2.8. Upgrade Drop Tube and Drop Tower experiment apparatus capability through continual evaluation of experiment and operational requirements.

2.8.1. In addition to the detectors required for temperature measurement of falling drops, UAH personnel have made a number of improvements to increase the productivity of the Tube and improve upon the data collection process for the facilities. Continual upgrading of the High Speed Data Acquisition systems includes a

Nicolet Transient Digitizer, which is interfaced to the silicon detectors along the tube. In addition we have maintained the video capability to observe samples during the sample heating and melting periods in the belljar. These systems are still working quite well. We are also still using an optical disk for archiving drop facilities data. A number of modifications have been made to improve upon the ease of sample changing in both the belljar and the catch tube. These modifications have been instrumental in improving control of samples during processing and quicker turn-around time in running experiments.

2.8.2 A Drop Tower User's Manual has been prepared by Jeff Synex and will probably be available during the next contract period. Due to the down scoping of that activity, we have not pushed for publication of the document.

2.9. Modify, as required, the drop tube and drop tower experiment packages associated with MSFC approved experiments and conduct drops necessary to support the investigation. Continuous improvement in the operational characteristics of both facilities has occurred. For instance the Drop Tube has improved the vacuum attainable by increasing the number of pumps, improvement in temperature measurements with both a new optical pyrometer and new detectors, and evolving redesigns in sample holders and retrieval systems. Also notable in terms of determining recalescence in undercooled samples is the addition of a video camera looking up the tube from the bottom. If recalescence does occur, it is

captured on the video tape for comparison with the data from the Si detectors. Some discussion has occurred with respect to using this data for temperature determinations during the drop; however, the complexity of the task makes it less desirable than using the Si detectors at this time. With improvements in CCD's and imaging systems in the future, we may reconsider this capability again.

2.10. Analyze experimental results and prepare reports.

2.11. Conduct special studies to define new experiments to be performed on the KC-135 aircraft and establish the requirements for the equipment to be used to carry out the experiments.

2.11.1. Guy Smith and his staff have also continued to work on the construction of a three-zone ADSF for the KC-135 experiments in parallel with all the other activities being performed for KC-135 experiments. It also will probably be ready for flight during the next contract period. The major problem facing KC-135 ~~purpose activity~~ is that we certainly will not be able to fly

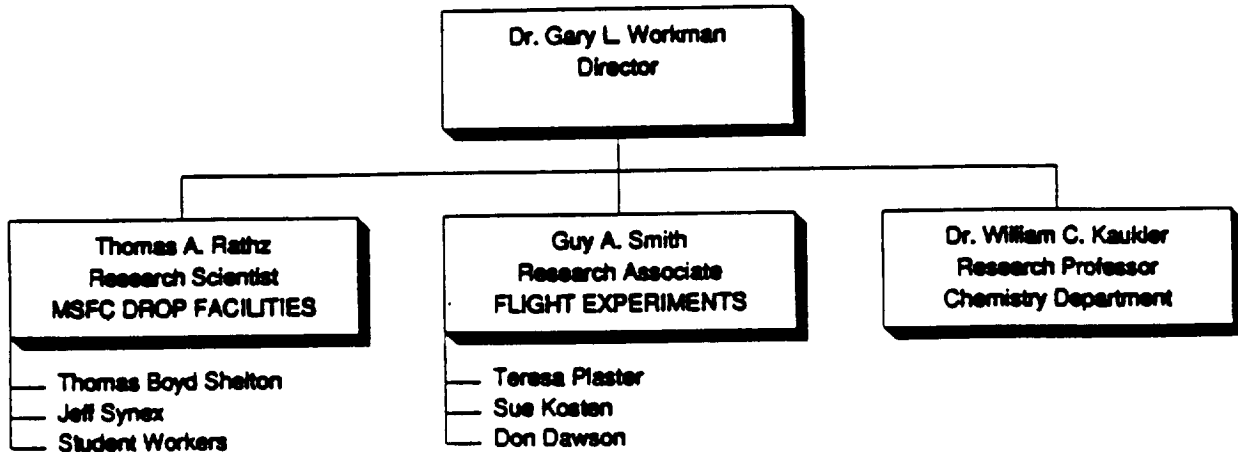
sufficient planning there would be more optimal control for implementation of all the furnaces.

2.11.2 Additional activities which have supported other experiments flying on the KC-135 include assistance with the Polymer Video Furnace and Rapid/Melt Rapid Quench Furnaces and making temperature measurements for the Orbital Tube Welder of Richard Poorman/MSFC. All of these activities were partially supported to cover additional hardware and travel expenses caused by their implementation.

2.11.3 The most useful contribution during this reporting period has been the modification to the ADSF to emulate the RM/RQ furnace.

2.12. Set optical pyrometer calibration test facility to include calibration, and associated equipment necessary to insure drop tube optical pyrometer calibration.

JOHNSON RESEARCH CENTER MATERIALS PROCESSING LABORATORY



4.0 Acknowledgements

The work performed on this contract was successful due to the fact that many people were able to provide help and assistance in meeting the above goals. This includes Dr. Robert Shurney, NASA/MSFC and Mr. Robert Williams, NASA/JSC in the KC-135 program, Dr. Mike Robinson and Kevin Vellacott-Ford at the Drop Facilities, and of course, the many UAH personnel who have worked with each of the facilities reported here.